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# UNIVERSITY OF IOWA STUDIES

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VOLUME II NUMBER 2

# SCALES FOR MEASURING RESULTS OF PHYSICS TEACHING

BY

HAROLD LAVERNE CAMP

PUBLISHED BY THE UNIVERSITY, IOWA CITY

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UNIVERSITY OF IOWA

STUDIES IN EDUCATION

CHARLES L. ROBBINS, Ph. D., Editor

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# SCALES FOR MEASURING RESULTS OF PHYSICS TEACHING

## INTRODUCTION

Every person who is familiar with the present situation in the teaching of high school physics feels the need of scientific investigation to aid in solving a number of vital questions. Some of the more significant of these are the following. To get the results sought, how much time should be spent in performing experiments in the laboratory? Do the results of laboratory work justify the expense involved in furnishing several sets of equipment? How should the time for the study of high school physics be distributed between work in the laboratory, learning the fundamental principles, solving problems, actual time in recitations, and observing classroom demonstrations? How should the pupil's total grade be determined? How may the course of study be revised to meet the needs of the majority more satisfactorily?

In attempting to solve some of these problems one is confronted with the desirability of some tests or scales with which to measure ability or achievement. With suitable means of measuring ability one can determine the amount of improvement in the given ability due to any given method used. Evidently a suitable means of measuring must be objective. The personal, or subjective, element must be eliminated, in order to arrive at accuracy similar to that obtainable with the meter-stick or the foot-rule (9, 12).*

The purpose of this study is to derive scales for measuring the results of physics teaching and to show some of their uses and applications as means of objective measurement. It is hoped that the results of this investigation may prove to be of some value in solving some of the many problems confronting physics instructors and supervisors.

*Numbers in parentheses refer to items in the bibliography.

## ANALYSIS OF THE PROBLEM

### IMPORTANT AIMS

In Dr. H. A. Greene's investigation of the Status of the Sciences in North Central High Schools (5), we find the relative importance of the various aims of science teaching as determined by (a) personal judgments of 101 science teachers and (b) analysis of the courses of study. The rating of the five most important aims follows:

| | | (a) | (b) |
|---|---|---|---|
| 1. | To give knowledge of natural phenomena | 1 | 1 |
| 2. | To serve as guide for daily life | 2 | 2 |
| 3. | To give scientific attitude | 3 | 4 |
| 4. | To prepare for college entrance | 4 | 6 |
| 5. | To give familiarity with subject matter | 5-6 | 3 |

If these results afford a correct basis, it is evident that the first two indicate the most important aims in the teaching of high school physics. Consequently the scale to be developed must measure (a) knowledge of the fundamental principles and (b) ability to put this knowledge to use in solving problems one meets in ordinary life.

### DEFINITION OF THE PROBLEM

The problem, then, is to formulate and select exercises, the correct handling of which involves the above phases of ability. Next, the difficulty of the different exercises must be determined in some way. Upon the assumption that the more difficult the exercise which a given pupil can barely solve correctly the greater is that pupil's physics ability, the difficulty of the hardest question the pupil can answer will be indicative of that pupil's ability. Therefore it is necessary to obtain exercises whose difficulties range from very easy to a little more difficult and more and more difficult to some that are extremely difficult. Such a scale of exercises would enable one to locate quite accurately the relative ability of any individual or group.

## METHODS OF EVALUATING TEST MATERIAL

There are two common methods of evaluating test-material. One of these, the method of judgments (13), finds the value or difficulty of an exercise to be the summation of the opinions of a large number of persons. The other method involves submitting the exercises to individuals in the very field in which the final tests or scales are intended to be used ultimately as a measure.

Of this last method there are several possibilities. The relative difficulty of the different test-exercises may be determined by the average time necessary to solve, by the Time-Error method (8, 10), by the Per Cent of pupils that solve correctly (1, 2), and by the Probable Error, or P. E. method (3, 6, 7, 14, 15).

### THE P. E. METHOD

The P. E. method has been more commonly used than any other for evaluating test-material. It was used by Buckingham, Greene, Hotz, Trabue, and Woody in developing their respective scales, and is used in this study.

By this method the relative difficulty of a given test-exercise depends upon the percentage of individuals who solve it correctly, regardless of the time required. Furthermore, it is assumed that the distribution of abilities, of which the exercises are designed to be a measure, conforms to the Normal Curve of Frequency.

In evaluating the test-exercises included in the scales reported in this study, it has been assumed that the distribution of physics abilities does conform very approximately to the Normal Distribution. This assumption is in a measure justified, as will be seen by examining data shown by Table I, and Figures 1, 2, 3, 4, 5, and 6.

### THE ZERO POINT

After determining the relative difficulties of the test-exercises by the P. E. method it is necessary to select an arbitrary zero point, or point of departure. A test-exercise so easy that only one in 10,000 would fail to solve it correctly was assumed as an exercise of zero difficulty. Its location on a linear scale of difficulty would be 6 P. E. (4 sigma) units below the position of an exercise of median difficulty. Beginning at such a point, all the test-exercises were located on the linear scale and were assigned values accordingly. Thus the exercise of median difficulty was given a value of 6 and others were given values greater or less as illustrated by Table II and Figures 7 and 8.

TABLE I: *Distribution of Scores**

| | A | | B | | C | | D | | E | | F | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scores* | *N* | *%* | *N* | *%* | *N* | *%* | *N* | *%* | *N* | *%* | *N* | *%* |
| 90–100 | 7 | 1.1 | 2 | .24 | 9 | .6 | 24 | 1.5 | 9 | .5 | 33 | .9 |
| 80–89.99 | 28 | 4.4 | 13 | 1.6 | 41 | 2.8 | 58 | 3.7 | 29 | 1.6 | 87 | 2.5 |
| 70–79.99 | 48 | 7.5 | 39 | 4.7 | 87 | 5.9 | 100 | 6.4 | 76 | 3.9 | 176 | 5.1 |
| 60–69.99 | 75 | 11.7 | 55 | 6.6 | 130 | 8.8 | 135 | 8.7 | 110 | 5.7 | 245 | 7.0 |
| 50–59.99 | 121 | 18.8 | 130 | 15.5 | 251 | 17.0 | 233 | 15.0 | 218 | 11.3 | 451 | 12.9 |
| 40–49.99 | 106 | 16.5 | 141 | 16.8 | 247 | 16.7 | 285 | 18.3 | 299 | 15.5 | 584 | 16.8 |
| 30–39.99 | 112 | 17.4 | 154 | 18.4 | 266 | 18.0 | 252 | 16.2 | 355 | 18.4 | 607 | 17.4 |
| 20–29.99 | 86 | 13.4 | 154 | 18.4 | 240 | 16.2 | 255 | 16.4 | 377 | 19.5 | 632 | 18.1 |
| 10–19.99 | 42 | 6.5 | 104 | 12.4 | 146 | 9.9 | 147 | 9.5 | 277 | 14.4 | 424 | 12.2 |
| 0– 9.99 | 18 | 2.8 | 45 | 5.4 | 63 | 4.3 | 66 | 4.2 | 180 | 9.3 | 246 | 7.1 |
| Total | 643 | | 837 | | 1480 | | 1555 | | 1930 | | 3485 | |
| Median | 46.0 | | 37.5 | | 41.0 | | 42.0 | | 33.7 | | 37.3 | |
| M. D. | 16.3 | | 15.7 | | 16.4 | | 17.0 | | 15.9 | | 20.0 | |
| Q. R. | 14.25 | | 14.2 | | 14.6 | | 12.85 | | 13.95 | | 14.75 | |
| Coëff. | 31.0 | | 37.9 | | 35.6 | | 30.6 | | 41.4 | | 39.6 | |

*Distributions A, B, and C refer to scores made in solving exercises on Heat and Electricity and Magnetism; D, E, and F refer to scores made in solving exercises on Mechanics, Heat, and Electricity and Magnetism; A and D refer to scores made by boys; B and E refer to scores made by girls; and C and F refer to scores made by boys and girls. N means Number of cases; % means percentage of all cases in a given group; M. D. means Mean Deviation from median; Q. R. means Quartile range; Coëff. means Pearson's "Coëfficient of variation."

Distributions A, B, C, D, E, and F are shown graphically by figures 1, 2, 3, 4, 5, and 6, respectively.

## ACTUAL DERIVATION OF THE SCALES AND TESTS

In a scale for the measurement of any given ability it is desirable to have test-exercises of various degrees of difficulty, ranging by gradual steps from those which are quite easy to those which are very difficult. To allow for the inevitable piling up of exercises that are of practically the same difficulty, one

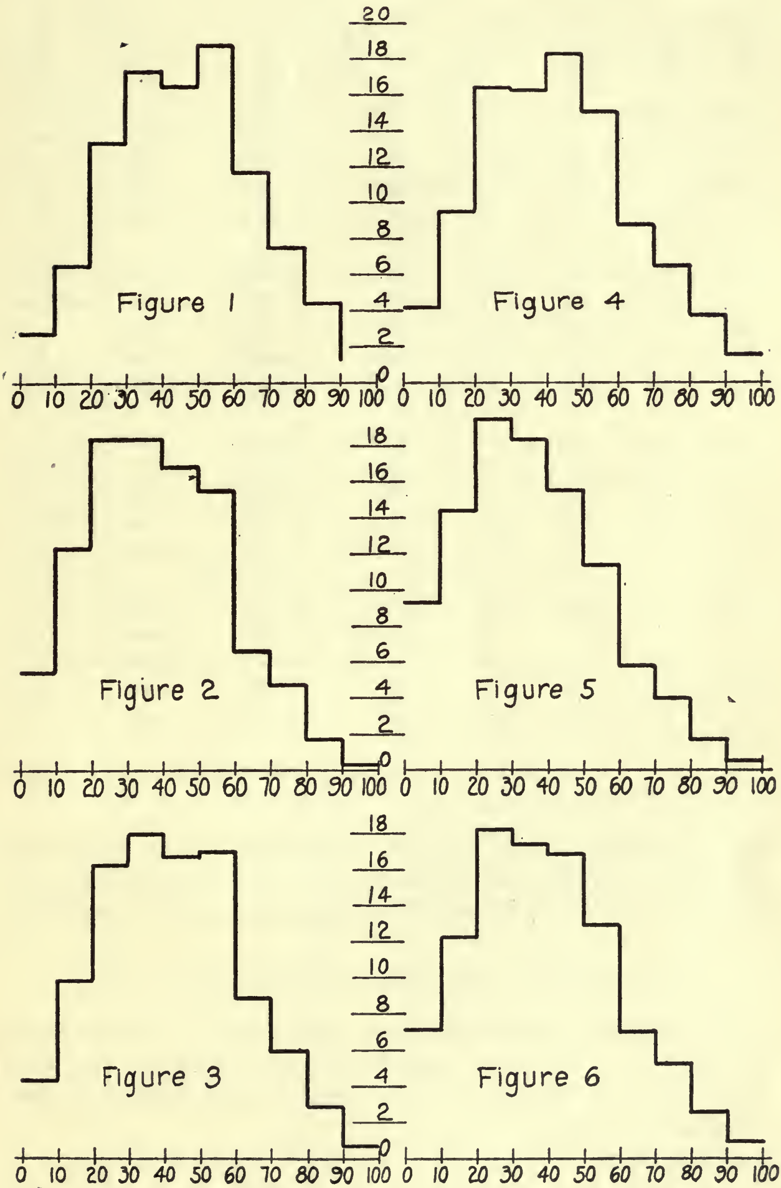


Figure 1
Figure 2
Figure 3
Figure 4
Figure 5
Figure 6

TABLE II*

| *Exercise number* | *Cases wrong* | *Cases correct* | *Total* | *Per cent correct* | *%-50%* | *P. E. value* | *Assigned value* |
|---|---|---|---|---|---|---|---|
| 2 | 16 | 59 | 75 | 78.6 | 28.6 | 1.176 | 4.8 |
| 6 | 70 | 5 | 75 | 6.67 | —43.33 | —2.226 | 8.2 |
| 11 | 34 | 72 | 106 | 67.9 | 17.9 | .689 | 5.4 |
| 18 | 38 | 70 | 108 | 64.9 | 14.9 | .567 | 5.4 |
| 21 | 55 | 25 | 80 | 31.2 | —18.2 | — .727 | 6.8 |
| 25 | 66 | 25 | 91 | 27.5 | —22.5 | — .886 | 6.8 |
| 26 | 61 | 18 | 79 | 22.8 | —27.2 | —1.105 | 7.2 |
| 31 | 40 | 42 | 82 | 51.25 | 1.25 | .046 | 6.0 |
| 33 | 71 | 11 | 82 | 13.4 | —36.6 | —1.643 | 7.6 |
| 40 | 42 | 23 | 65 | 35.4 | —14.6 | — .555 | 6.6 |
| 43 | 52 | 12 | 64 | 18.75 | —31.25 | —1.316 | 7.4 |
| 45 | 34 | 28 | 62 | 45.2 | — 4.8 | — .179 | 6.2 |
| 46 | 49 | 11 | 60 | 18.3 | —31.7 | —1.340 | 7.4 |
| 52 | 28 | 38 | 66 | 57.6 | 7.6 | .284 | 5.8 |
| 55 | 55 | 11 | 66 | 16.7 | —33.3 | —1.432 | 7.4 |
| 56 | 66 | 83 | 149 | 55.7 | 5.7 | .213 | 5.8 |
| 57 | 43 | 106 | 149 | 71.2 | 21.2 | .829 | 5.2 |
| 63 | 79 | 4 | 83 | 4.82 | —45.18 | —2.465 | 8.4 |
| 65 | 44 | 88 | 132 | 66.7 | 16.7 | .640 | 5.4 |
| 66 | 45 | 83 | 128 | 64.9 | 14.9 | .567 | 5.4 |
| 67 | 105 | 5 | 110 | 4.54 | —45.46 | —2.508 | 8.6 |

must formulate a large number of exercises. With these facts in mind, a large number of test-exercises were formulated, many more than were later submitted to high school pupils for solution.

### REQUIREMENTS WHICH THE EXERCISES MUST FULFIL

In order that the test-exercises might really be suitable for the purposes of objective measurements, the following principles from Chapman (4) were adopted as requirements that each test-exercise must fulfil:

*Table II illustrates the method of determining relative difficulties of test-exercises in P. E. units, and assigning final values. The method of assigning final values is illustrated graphically by Figures 7 and 8.

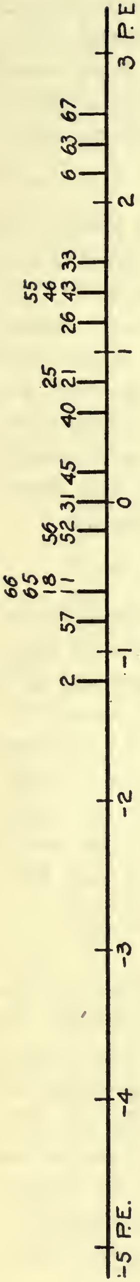


Figure 7.

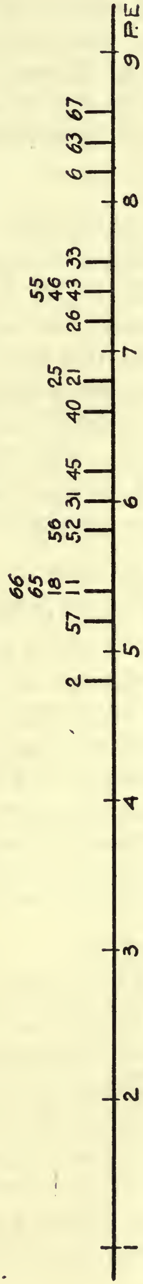


Figure 8.

1. "It must apply specifically to the field of knowledge for which the test is constructed.

2. "It must be taken from an essential part of the subject which is contributory to understanding or summarizing a general theory or principle. The question, in other words, should be such that a correct answer would indicate that a distinct meaning had been grasped.

3. "It must be so worded as not to be ambiguous.

4. "It must be so framed that it can be answered very concisely, usually in a single word or at most by a short phrase.

5. "It must be such that the short answer given in the test includes all possible correct answers."

As mentioned on page 6, it seems best to develop a scale to measure two phases of physics ability, namely, (a) knowledge of the fundamental principles, and (b) ability to put this knowledge to use in solving problems one meets in ordinary life.

It was further decided to include only those facts, principles, and laws of physics that are quite commonly taught in courses in high school physics.

Dr. Daniel Starch made a careful analysis of five text-books (Black and Davis, Carhart and Chute, Hoadley, Mann and Twiss, and Millikan and Gale), most commonly used for high school physics, and found 102 principles common to all five of them. These results were used as a guide in formulating the test-exercises (11).

### EXERCISES FOR MECHANICS, HEAT, AND ELECTRICITY AND MAGNETISM

In most cases the course in high school physics is divided into five main phases: Mechanics, Heat, Light, Sound, and Electricity and Magnetism. It is desirable to have objective measurements for each of these phases, but this study is confined to obtaining suitable means of measuring abilities in what are perhaps the three most important phases, namely, Mechanics, Heat, and Electricity and Magnetism. Therefore the test-exercises were developed in three distinct groups, those in each group being designed to measure ability in one phase of physics.

### THE PRELIMINARY TESTS

The test-exercises were arranged in 47 different preliminary tests, of nine or ten exercises each. Correct solutions of these exercises were attempted by approximately 3500 boys and girls in 129 of the best high schools in Iowa. Each test was distributed over the state so that the pupil-reactions on the exercises included in it would be representative of the state as a whole. Each exercise was attempted by an average of 99 different pupils (minimum 60) and each test was given from eight to ten weeks after the work in that particular phase of physics had been finished.

### THE FINAL SCALES

Tables III-A, III-B, and III-C show the final scales for Mechanics, Heat, and Electricity and Magnetism, respectively. In Table III-A all the exercises for Mechanics are grouped so that all of a given value are together. For example, for the value 3.4 there is one exercise, No. 9; for the value 3.8, three, Nos. 47, 201, and 217; and for the value 5.8, nine. In the parentheses at the right of each exercise is the number which represents the average amount of time spent by those who correctly solved that particular exercise, not including the time spent by those who failed to solve it correctly. For example, on page 15, the 'average time' for exercise No. 52 is 3.3 units, while that for exercise No. 100 is 2.5 units and for exercise No. 135 is 4.1 units. Each unit showing the 'average time' is equal to 30 seconds. Tables III-B and III-C show similar data for the exercises on Heat, and Electricity and Magnetism, respectively.

TABLE III-A

MECHANICS

| *Value* | *Exercise* | *Time* |
|---|---|---|
| 3.4 | | |
| | 9. What is the common name of the instrument used to measure the pressure of the atmosphere? | (1.7) |
| 3.8 | | |
| | 47. What is the name of the force which causes objects to move toward the center of the earth? | (1.5) |
| | 201. If V equals AT, and A means acceleration, and T means time, what does V mean? | (1.8) |
| | 217. D equals M/V. If M means mass, and V means volume, what is D? | (1.7) |
| 4.2 | | |
| | 39. Which is stronger, cohesion between mercury particles or adhesion between glass and mercury? | (1.9) |
| | 113. If a pound ball falls 100 feet and all its energy is transformed into work, how much work will be done? | (2.8) |
| | 191. How far must a force of 150 pounds move in doing 1200 foot-pounds of work? | (2.5) |
| 4.4 | | |
| | 3. A clock loses time. Should its pendulum be lengthened or shortened? | (1.5) |
| 4.6 | | |
| | 14. What is the common name for the rate of change of velocity? | (2.1) |
| | 71. If the elastic limit of a certain spring-balance is 10 pounds, the spring will come back to its original size and condition after weighing objects of less than 10 pounds. Because of a stress due to 2 pounds the spring lengthens 1 centimeter, how much will it lengthen for a stress due to 8 pounds? | (3.1) |
| 4.8 | | |
| | 2. A force of 50 pounds is used to do 1000 foot-pounds of work. Through what distance does the force move? | (2.4) |

129. In the formula, W equals FS, W stands for work and F stands for force. For what does S stand? (1.9)

206. For a pendulum swinging with a small amplitude, T is proportional to the square root of L/g where L is the length of the pendulum, and g is the acceleration due to gravity. What is meant by T? (2.5)

210. In the ordinary electric light bulb there is little or no air. When a bulb is broken, will the glass start moving toward the center or away from the center of the bulb? (1.7)

5.0

34. If two adjacent sides of a parallelogram represent 2 forces, what line may be drawn to exactly represent the resultant? (1.9)

119. A certain mass resting on a table presses down on it with a force of 20 dynes. With what force does the table press upward against the mass? (2.4)

179. Two glass tubes are placed with their lower ends in water. The water rises, in both tubes. The diameters of the tubes are 1 millimeter and 2 millimeters, respectively. In which tube will the water rise higher, the 1mm. or the 2mm. tube? (2.4)

184. How much work is possible from the potential energy of 500 pounds of water which is 100 feet above the ground. (3.8)

5.2

57. What does the barometer measure? (2.4)

120. A blotter absorbs ink when one corner touches the ink. What is the common name applied to such action? (1.8)

139. The weight of 5 cubic centimeters of mercury is 68 grams. What is the density of mercury? (3.6)

163. During a storm the barometer reading dropped suddenly and at the same time several store windows were broken by the sudden change in the atmospheric pressure. Did the windows cave in toward the store or burst out toward the street? (2.1)

5.4

11. A certain mass weighs 50 pounds. What would its weight be if the force of gravity were doubled? (2.2)

18. For wheeling an object which is tall, which is better, a wheel-barrow with handles 1.8 feet apart, or one with handles 2.6 feet apart? (2.4)

65. A force of one dyne acting on a certain mass gives it an acceleration of one centimeter per second per second. What is the amount of the mass? (3.0)

66. What is the common name for the one factor that causes a difference between mass and weight? (2.5)

75. What is the common name of that property of matter because of which any mass resists all attempts to change its direction or amount of motion? (2.8)

92. What is the common name of the energy a body possesses because of its motion? (1.9)

104. What is the density of ice when 100 cubic centimeters weighs 92 grams? (2.9)

161. Two glass tubes one inch in diameter stand in a vertical position with their lower ends in water. Both tubes are full of dry dirt (earth), but in one the dirt is finely pulverized. In which tube will water rise higher, in course dirt or in fine dirt? (2.2)

166. A mass increased in velocity from 20 feet per second to 50 feet per second with a constant acceleration of 3 feet per second per second. How long did it take to make the change? (5.8)

216. For small arcs of vibration of a pendulum, T equals 2 pi times the square root of L/g. If T is the time of one complete vibration and g is the acceleration, what is L? (2.6)

224. What is the common name for the attraction between particles of like material? (1.9)

5.6

54. What is the common name for the property of matter whereby any body continues to move in the same straight line without change of velocity unless changed by an outside force? (2.3)

152. A bar of gold is exactly 12 inches long, 4 inches wide, and 2 inches thick. It rests in a horizontal position and in a direction straight north and south. How far from the south end is the center of gravity? (4.8)

171. Two forces, of 20 pounds and 60 pounds respectively, act in opposite directions. What is their resultant force? (3.1)

220. The density of lead is 11.4. What is the weight of 100 cubic centimeters of lead? (3.7)

5.8

8. What is the efficiency of a machine when a force of 50 pounds acting through a distance of 30 feet lifts 200 pounds 6 feet? (4.8)

52. If "d" is the distance a load is lifted by a force while moving through a distance "s" what is the mechanical advantage of the arrangement? (3.3)

56. The area of one of the pistons of a hydraulic press is 120 times as great as the area of the other. What is the mechanical advantage of the machine? (3.0)

100. What is the density of a block of wood that floats ¾ under water? (2.5)

102. 300 cubic feet of gas at a pressure of 75 pounds per square inch are compressed to 60 cubic feet. What is the pressure then? (3.7)

131. What is the common name for the energy of a weight which is being held up a certain distance above the ground? (2.8)

135. Two opposing football teams average 140 and 150 pounds per man, respectively. The lighter team charges against its opponent with a velocity of 25 feet per second, the heavier team charges with a velocity of 24 feet per second. Which team has the advantage due to the momentum, the lighter or the heavier? (4.1)

154. A boat is moving northward at the rate of 20 miles per hour, while a steady wind blows from the east at 20 miles per hour. To one standing on the front end of the boat, from what direction will the wind seem to come? (3.4)

174. When ink is soaked up into a blotter, which force is the stronger, adhesion or cohesion? (2.3)

6.0

7. Momentum is measured by the product of two numbers, one of which is the mass. What is the other? (1.5)

31. What is the common name for the work done when a force of one dyne acts through a distance of one centimeter? (2.0)

38. Water weighs 62.4 pounds per cubic foot. A tank has water in it 50 feet deep. What is the pressure on the bottom of the tank in pounds per square foot? (3.0)

58. A steel tank of hydrogen is full at a pressure of 200 pounds per square inch. Hydrogen is drawn off until the pressure has dropped to 40 pounds per square inch. What fractional part of the original amount of gas has been drawn off? (4.5)

112. What is the common name for the point of application of the resultant of all parallel forces that make up the weight of a body? (2.3)

138. Two forces, A and B, can produce an acceleration of a lead ball of 50 feet per second per second and 75 feet per second per second respectively. B is how many times as large as A? (4.9)

157. What is the common name for the weight per unit volume? (3.6)

202. What is the common name for the "capacity for doing work"? (2.7)

6.2

5. The weight of 5 cubic centimeters of a certain substance is 68 grams. What is the density of the substance? (3.0)

13. What is the common name for the force which gives to a mass of one gram an acceleration of one centimeter per second per second? (2.1)

45. A stick is 101.6 centimeters long. What is its length in inches? (4.3)

48. A trap door three feet wide lies in a horizontal position when closed. A vertical force of 100 pounds applied 6 inches from the outer edge is needed to open it. What is the moment of the force? (4.3)

85. Shot are made by pouring molten metal through a sieve on top of a tall tower and catching it in water at the bottom. What is the name of the force that causes them to become spherical? (3.9)

137. A block and tackle has three lengths of rope between the movable and stationary blocks. What is the mechanical advantage? (2.6)

208. What is the common name for the attraction between particles of unlike materials? (2.7)

6.4

122. Under a pressure of 15 pounds per square inch a certain mass of air has a volume of 100 cubic feet. What volume will the same mass of air have when it is under a pressure of 300 pounds per square inch? (5.0)

153. Potential energy is measured by the product of 2 numbers, one of which is the force. What is the other? (3.3)

162. What is the total force applied to a brake piston whose radius is 6 inches, if the pressure applied is 72 pounds per square inch? (7.6)

219. What is the barometer reading in inches which corresponds to a reading of 740 millimeters? (4.7)

6.6

40. Water weighs 62.4 pounds per cubic foot. A tank has water in it 50 feet deep; what is the pressure on the bottom of the tank in pounds per square inch? (7.9)

155. What is the numerator of a fraction whose denominator is *force* if the fraction represents the mechanical advantage? (3.0)

165. A force of 100 dynes acts through a distance of 1000 cm. What work is done by the force? (3.2)

215. What is the common name for the product of a force and the perpendicular distance from the axis of rotation to the line of action of the force? (1.2)

6.8

1. What horse-power is necessary to do 1100 foot-pounds of work in 5 seconds? (4.8)

12. What force will give a mass of 10 grams an acceleration of 50 centimeters per sec. per sec.? (4.7)

21. Under a pressure of 15 pounds per square inch a certain mass of air has a volume of 100 cubic feet. What volume will the same mass of air have when under a pressure of 300 pounds? (5.3)

25. The acceleration due to gravity is 32.16 feet per second per second. How deep is a ravine if it takes 5 seconds for a stone to fall to the bottom? (5.3)

44. The engine drives a boat with a speed of 15 miles per hour. With the current 3 feet per second, how long will it take to go down stream 50 miles? (9.7)

72. What is the kinetic energy of a mass of 20 grams whose velocity is 10 centimeters per second? (5.6)

82. The volume of a tank is 1.5 cubic feet and it is filled with air until the compressed air is under a pressure of 1500 pounds per square inch. How many cubic feet of air would this make when allowed to expand under a pressure of 15 pounds per square inch? (5.8)

94. How long will it take a 10 horse-power engine to do 11,000 foot-pounds of work? (4.3)

121. When the barometer reads 762 millimeters, what does it read in inches? (4.0)

148. By means of an arrangement of pulleys and a cord, a mass of 2200 grams was moved through a distance of 100 centimeters. What was the work done? (3.7)

7.0

49. To measure kinetic energy we multiply ½ the mass by what number? (1.7)

111. What will be the velocity of a body after falling 10 seconds if it starts from rest with a constant acceleration of 980 centimeters per second per second? (2.8)

140. During a storm the barometer reading dropped 1.5 inches. What would have been the drop if the barometer were a water-barometer instead of a mercury-barometer? (3.7)

175. The density of glycerine is 1.26 and the density of mercury is 13.6; for a mercury barometer reading 76 centimeters what would be the corresponding reading on a glycerine barometer? (9.6)

182. How much work can a 40 horse-power engine do in an hour? (4.5)

7.2

19. What is the common name applied to the time rate of doing work? (4.9)

20. How many times is a pendulum vibrating in the same phase during 20 complete vibrations? (4.4)

26. What is the moment of a force when the force is 10 pounds and the point of application of the force is also the axis of rotation of the body to which the force is applied? (3.9)

73. How many foot-pounds of work can be done by a 2 horse-power engine in 8 hours? (6.6)

83. A weight of 50 pounds is placed 15 inches from the fulcrum of a lever of the second class. The effort needed to move the weight is 5 pounds. What is the total length of the lever? (5.3)

118. What horse-power is necessary to do 330 foot-pounds of work every 6 seconds? (3.5)

198. For each 90 foot variation in altitude the barometer reading varies about .1 inch. An aviator recorded the reading of his barometer when he was flying at 4000 feet, and 10 minutes later he observed that the barometer reading was 3 inches less. At what altitude was he flying then? (6.5)

227. A force of 36 pounds acts through a distance of 4 feet and moves a load 6 inches. What is the load? (3.8)

7.4

35. Force times distance divided by time gives what? (1.4)

43. If the front sprocket wheel of a bicycle has 24 sprockets and the rear one has 8, how far will one complete turn of the pedals drive a 28 inch wheel? (6.9)

46. If a force of 1 gram acts on a mass of one gram, what will be the resulting change in velocity of the mass? (3.3)

55. The period of vibration of a pendulum is one second. What is the period of vibration of another pendulum whose length is four times as great? (4.9)

76. A pendulum vibrates with a period of 1 second. What will be the length of a pendulum whose period of vibration is ½ second? (3.3)

101. The density of mercury is 13.6, what is the atmospheric pressure per square centimeter when the barometer reading is 750 mm.? (6.1)

146. A ferry boat weighs 700 tons. What will be the displacement of water, in cubic feet, when a load of 600 tons is added? (6.6)

164. A pressure gauge registered zero at the surface of a fresh water lake and 150 pounds per square inch at the bottom. What was the depth? (6.0)

7.6

33. What is the common expression used to denote the smallest stress that will produce a permanent "set" in a body? (1.6)

89. A force of 150 dynes acts on a mass of 5 grams. What will be the change in the velocity of the mass (per second)? (7.5)

7.8

96. Two simple pendulums have masses of 2 grams and 20 grams, respectively; the period of vibration of the former is .5 second, what is the period of vibration of the latter? (3.1)

207. A water tank has a flat bottom whose area is 150 square feet and the water in the tank is 80 feet deep, what is the total downward force on the bottom of the tank? (5.3)

209. What is the pressure of the atmosphere at sea level, in grams per square centimeter? (1.2)

218. How high will water rise in the pipes of a tall building if the pressure gauge shows a pressure on the ground floor of 26 pounds per square inch? (4.8)

8.0

109. For wheeling a 300-pound load of sand which is better, a wheel-barrow with handles 2 feet long, or one with handles 2.5 feet in length? (2.3)

110. The foot-pound, the kilogram-meter, the gram-centimeter, and the erg are measures of what? (1.8)

145. How much coal can a 40-horse-power engine lift out of a mine 400 feet deep in 10 hours? (7.2)

147. A mass of 4 grams is moving with a velocity of 4 centi meters per second when a force of 16 dynes acting in the same direction is imposed upon it. What will be the velocity of the mass one second later? (5.9)

197. If the barometer reading never falls below 26 inches of mercury (density 13.6), within what distance of the bottom of a well 50 feet deep should the piston of an iron pump be placed so the water can be pumped out until the well is dry? (5.0)

8.2

6. What is the common name for the measure of the earth's attraction for any given mass? (2.4)

32. A body falls with an acceleration of 10 centimeters per second per second. After falling for 5 seconds it has a velocity of 50 centimeters per sec. What was its original velocity? (2.3)

81. What is the common name for the force which causes mercury in a narrow glass tube to have a convex surface? (1.8)

91. The moment of a force is equal to the product of 2 numbers, one of which represents the perpendicular distance from the axis of rotation of the body to the line of action of the force applied. What does the other factor of the product represent? (5.7)

108. What is the difference between kinetic energy of a pound mass moving at the rate of 500 feet per second and the kinetic energy of a 500 pound mass moving at the rate of one foot per second? (3.3)

130. With an acceleration of 5 feet per sec. per sec. How many seconds will be needed for a body to fall 360 feet? (5.1)

144. The cross-sectional area of the piston of a steam engine is 150 square inches. The live steam, (in the gaseous state), is under a pressure of 1000 pounds per square inch before the piston moves. Its volume is doubled, due to expansion, when it moves the piston a full stroke of 12 inches. How much work is done by one such expansion of the steam in moving the piston one full stroke? (9.5)

156. For small arcs of vibration of a pendulum T equals 2 $\pi$ times the square root of L/g, in which T is the time for a complete vibration, and L is the length of the pendulum. What is g? (6.7)

180. What is the possible buoyant force of 78 pounds of cork whose density is 15.6 when water weighs 62.4 pounds per cubic foot? (4.5)

8.4

36. A machine is so arranged that a force of 5 pounds acting through a distance of 100 inches moves an opposing force of 250 pounds through a distance of 2 inches. What is the mechanical advantage of the machine? , (3.8)

63. A well was dug 10 feet deep and four feet in diameter. How much work was done in raising the dirt to the surface if each cubic foot of dirt weighs 150 pounds? (12.0)

188. A force of 20 dynes increased the velocity of a body from 40 centimeters per second to 60 centimeters per second. This change was produced in 2 seconds. How many grams did the body weigh? (4.8)

200. A mass of 36 grams was found to be gaining in velocity, 3 centimeters every second. What force was necessary to cause the change? (3.3)

8.6

67. What acceleration will cause the velocity of a body to change from 46 ft. per second to 88 ft. per second in 7 minutes? (5.0)

84. To acquire a speed of 60 miles an hour how far would an an express train have to run provided it started from rest and its motion were uniformly accelerated 8 feet per second per second? (19.8)

9.0

62. While a train is running with a speed of 30 miles per hour a package is thrown perpendicularly from it with a horizontal velocity of 20 feet per second. What is the resulting horizontal velocity of the package with respect to the ground? (18.2)

199. Horses attached to a car pull at an angle of 30 degrees with the track and with a force of 1200 pounds. What is the amount of force pulling in the direction in which the car moves?, (13.0)

9.2

103. A ball whose mass is 100 grams is struck with a ball-bat and given a velocity of 40 meters per second. How much energy is imparted by the blow? (1.0)

126. A rectangular slab of stone 6 feet long, 3 inches wide, and 3 inches thick, and weighing 500 pounds, lies on the floor. How much work must be done in setting it on end? (6.0)

183. If the wheels of an electric car are 2 feet in diameter, the axle cog wheel is 8 inches, and the cog-wheel attached to the motor is 12 inches in diameter, what must be the speed of the motor to carry the car 1 mile in five minutes? (17.3)

9.4

95. At sea-level the force of gravity is 32.16 pounds. If a mass is pulled down by an additional force of 32.16 pounds, what will be the acceleration due to the two forces combined? (13.0)

9.8

173. A simple pendulum vibrates with a period of 2/3 second and a similar pendulum vibrates with a period of 2/9 second. The latter is how many times as long as the former? (4.0)

## TABLE III-B

### HEAT

| *Value* | *Exercise* | *Time* |
|---|---|---|
| 3.2 | | |
| | 289. What is the common name of the process by which the sun transmits heat to the earth? | (1.6) |

297. What is the common name for the instrument which measures temperature? (1.2)

299. Radiation, convection, and conduction are three means of transmitting what? (1.1)

325. Does the earth radiate heat in every direction even toward the sun? (2.2)

3.8

257. From the following select a poor conductor of heat: wood, stone, air, copper, water, vacuum, iron. (1.8)

4.0

311. If an object is a good absorber of radiant heat is it a good reflector of heat? (1.9)

4.2

275. From the following select a good conductor of heat: wood, stone, air, copper, water, vacuum, iron. (2.0)

312. Which has the lower freezing point, fresh water or salt water? (2.1)

326. Two equal masses of copper have temperatures of 40 degrees Centigrade and 80 degrees Centigrade, respectively. Which will radiate heat faster, the former or the latter? (2.6)

329. Which will absorb radiant energy faster, a smooth surface or a rough surface of the same material? (2.5)

4.6

233. What is the common name for the amount of heat necessary to raise the temperature of one gram of water 1 degree Centrigrade? (1.6)

243. What will be the effect on the thermometer reading if the bulb is covered with a wet cloth? (2.4)

279. When a liquid evaporates what does it absorb from material adjacent to it? (2.9)

281. What is the common name for the action which takes place when an iron ball is warmed from 10 degrees C. to 20 degrees C.? (3.0)

291. On a certain day the air has only half enough moisture in it to make it saturated. What then is the relative humidity? (3.6)

292. If the pressure remains the same what fraction of its volume at zero will a mass of air increase in temperature for each rise of 1 degree Centigrade? (3.0)

5.0

246. What is the use of the radiator on an automobile? (3.0)

247. What does a thermometer measure? (1.9)

330. Why should the surface of a tea kettle be polished all except the bottom? (3.3)

5.2

234. The specific heat of aluminum is .218, of brass is .094, of copper is .095, and of iron is .113; if we have the same mass of each and all have the same temperature, which contains the most heat? (3.0)

237. At ordinary atmospheric pressure ice melts at 0 degrees C.; to make ice melt at —2 degrees C. would we increase or decrease the pressure? (3.1)

270. On the Fahrenheit thermometer how many degrees are there between the freezing point and the boiling point? (1.2)

288. Which would be heated more by 150 calories of heat, an ounce of copper or an ounce of aluminum? (2.9)

304. Which of the following represents the highest temperature: 95 degrees Centigrade, 194 degrees Fahrenheit, 90 degrees C.? (3.5)

321. Why does iron feel colder to the hand than wood? (3.1)

332. Why do we mix salt with the ice which we use in freezing ice cream? (3.6)

5.4

244. If equal quantities of heat are applied to equal masses of iron and water, which will show the greater change in temperature? (2.1)

248. How many calories of heat are given off by 150 grams of water in cooling from 90 degrees C. to 30 degrees Centigrade? (4.1)

263. Two masses of the same material have the same surface-area, weight, and temperature. But one is polished and the other is rough. Which will cool faster? (1.6)

302. At normal atmospheric pressure, water boils at 100 degrees C. To make water boil at 90 degrees Centigrade must the pressure be increased or diminished? (2.2)

317. What is the common name of the process by which heat is carried through substances that are at rest? (3.3)

319. In an air-tight room would starting an electric fan make the temperature of the room change? (2.6)

5.6

239. By what method of heat transmission does a grate fire heat a room? (2.6)

307. What is the common name of the process by which heat is carried from one place to another by a moving fluid? (1.7)

5.8

231. What is the reading on the Fahrenheit thermometer which corresponds to 20 degrees Centigrade? (3.8)

314. It took 150 calories of heat to raise the temperature of 50 grams of a certain metal 15 degrees on the Centigrade scale. What was the specific heat of that metal? (7.9)

331. Why does sprinkling the walks with warm water on a hot summer day make the walks and the air near the walks much cooler? (2.5)

6.0

254. A certain iron rod was found to be longer at 40 degrees C. than it was at 20 degrees C. What is the common name for an increase in volume due to an increase in temperatnre? (3.0)

301. At what temperature is the density of water the greatest? (1.5)

303. The temperature of a room is 72 degrees Fahrenheit; what is the reading on the Centigrade scale for this temperature? (4.1)

328. What is the coëfficient of cubical, or volume, expansion of a gas? (3.1)

6.2

261. Wind is a good example of what kind of heat transmission? (1.7)

284. On the ''Absolute scale'' what is the reading which corresponds to the temperature of melting ice? (4.5)

290. How many calories of heat are necessary to change 100 grams of ice at 0 degrees C. to water at 90 degrees Centigrade? (7.6)

295. In cooling 5 degrees Centigrade a mass of water gave off 100 calories of heat. What was the mass? (3.8)

308. Of the three means of heat transmission which does the hot-air furnace make the most use? (1.4)

6.4

274. How many degrees Centrigrade will 10 calories of heat warm 5 grams of water? (3.1)

313. The intensity of radiant heat is inversely proportional to what? (2.8)

6.6

272. What is the common name for the amount of heat needed for any substance to increase the temperature of 1 gram of it one degree Centigrade? (1.7)

300. What is the common name for the ratio of the increase in volume to the original volume, when the increase is due to a rise in temperature of 1 degree Centigrade? (2.3)

320. Will an object which absorbs heat readily be a good radiator of heat? (2.9)

6.8

245. The temperature of the air was 45 degrees Fahrenheit at noon and the following morning it was 0 degrees Fahrenheit. What was the drop in Centigrade degrees? (6.3)

256. If 75 grams of water at 35 degrees Centigrade is cooled until 300 calories of heat has been given off, what will be the final temperature of the water? (3.6)

258. The coëfficient of linear expansion of copper is .000017 and a copper wire is 300 feet long at 0 degrees Centigrade. What will be its length at 50 degrees Centigrade? (6.1)

7.0

253. What is the reading on the Fahrenheit thermometer corresponding to —40 degrees Centigrade? (2.7)

264. A certain mass of air has a volume of 13 liters at 0 degrees Centigrade, what will be its volume at 21 degrees Centigrade, the pressure remaining the same all the time? (6.9)

7.2

273. A Centigrade thermometer registers -20 degrees what is the corresponding reading on a Fahrenheit thermometer? (3.2)

276. A thousand calories of heat is equivalent to how many ergs? (8.2)

283. What is the common name of the process by which pure drinking water may be obtained from sea-water? (5.4)

322. How many Fahrenheit degrees does 100 Centigrade degrees equal? (3.6)

7.4

267. At 10 degrees C. a cubic meter of air contains 9 grams of water, at 20 degrees C. it contains 17 grams when saturated. If the air in a room is 20 degrees C. and we find its ''dew-point'' to be 10 degrees Centigrade, what is the relative humidity? (12.1)

310. If it takes 540 calories of heat to change 1 gram of water at 100 degrees Centigrade to steam at the same temperature, how many calories of heat will be necessary to change 10 grams of ice at 0 degrees C. to steam at 100 degrees Centigrade? (5.1)

323. If 1000 cubic centimeters of air at 15 degrees Centigrade be changed to 50 degrees Centigrade, what will be the volume so that the pressure remains the same as before? (12.3)

327. If 42700 gram-meters of energy is all converted into heat and used to melt ice, how many grams will it melt? (5.1)

7.6

235. From a point source of radiant heat, which of the following will receive more heat:
(a) one square foot of surface 5 feet away, or
(b) 5 square feet of surface 10 feet away, or
(c) 8 square feet of surface 15 feet away? (3.5)

236. If the coëfficient of linear expansion of steel is .000013, what length steel rail will increase in length 1/4 inch for an increase in temperature of 80 degrees Centigrade? (24.9)

238. How much steam at 100 degrees C. must be run into 500 grams of water at 10 degrees C. to raise it to 40 degrees Centigrade? (20.9)

265. If 40 grams of water at 100 degrees Centigrade are mixed with 10 grams of water at 20 degrees Centigrade, what will be the resulting temperature of the mixture? (8.8)

282. At what temperature on the Centigrade scale will a quart of air at 0 degrees expand to occupy 2 quarts, the pressure remaining constant? (6.8)

7.8

280. Two masses, A and B, are placed in air at 15 degrees Centigrade. The temperature of A is 95 degrees Centigrade and its rate of cooling is 4 times as great as the rate of cooling of B. What is the temperature of B? (8.3)

309. What is the common name for the number of work units which is equivalent to a calorie of heat? (3.2)

8.0

232. When we use the formula PV divided by T equals a constant, what value will T have for a temperature of 27 degrees Centrigrade? (5.0)

242. Two masses, A and B, have temperatures of 80 degrees C. and 40 degrees C., respectively. The medium surrounding them has a temperature of 20 degrees C. The rate of cooling of A is how many times as great as the rate of cooling of B? (4.1)

8.2

318. If 427 kilogram-meters of energy is all turned to heat, how many calories will it be? (2.7)

9.2

255. A liter of air is enclosed so it cannot increase in volume. If the pressure is 15 pounds per square inch when the temperaature is 20 degrees Centrigrade, what will be the pressure when the temperature rises to 80 degrees Centrigrade? (2.0)

9.4

262. If 427 gram-meters, (4.19 times 10 to the 7th. power ergs), is all turned to heat, how many calories will it be? (7.0)

TABLE III-C

ELECTRICITY AND MAGNETISM

| *Value* | *Exercise* | *Time* |
|---|---|---|
| 2.4 | | |
| | 425. From the following select one which is a poor conductor of electricity: graphite, glass, hard rubber, pure water, paper. | (1.6) |
| 3.0 | | |
| | 364. One foot of a certain wire has a resistance of 1 ohm, what will be the resistance of 100 feet of the same wire? | (2.7) |
| 3.6 | | |
| | 333. From the following select one material which has magnetic properties to a marked degree:—glass, wood, brass, iron, water, air. | (1.1) |
| 3.8 | | |
| | 365. What is the common name of the electromotive force needed to drive a current of one ampere through a resistance of one ohm? | (1.9) |
| 4.0 | | |
| | 334. When two substances are rubbed together, if one becomes positively charged, what will always happen to the other? | (1.2) |
| | 358. From the following select one which is a good insulator: paper, pure water, graphite, amber, dry air. | (2.5) |
| 4.2 | | |
| | 419. Telegraph lines are usually made of iron. Why are trolley wires usually made of copper? | (2.0) |
| | 433. Will positive electrification attract negative electrification? | (1.2) |
| | 435. What is the unit of resistance called? | (1.5) |
| 4.4 | | |
| | 338. What current is necessary to deposit .001118 grams of silver in one second? | (1.7) |
| | 348. When given the electro-motive-force and resistance of a circuit, what formula would you use to calculate the current? | (2.0) |
| 4.6 | | |
| | 414. What is the common name for the condition of a cell when a film of hydrogen has gathered on the positive plate? | (1.4) |
| | 415. A transformer has 10 turns of wire in the primary for each turn of wire in the secondary coil. The voltage in the primary is 1100, what is the voltage in the secondary? | (2.8) |
| 4.8 | | |
| | 357. If a hollow steel sphere is positively charged, will the entire charge be on the inner surface, on the outer surface, or scattered all through the material? | (1.8) |

5.0

372. What is the common name of the machine which transforms mechanical energy into electrical energy? (1.4)

376. The hard rubber plate of an electrophorus is charged with negative electrification and is used to charge the metal plate by induction. What kind of electrification will be induced on the metal plate? (1.8)

395. Of which of the following is the Leyden jar a good example: resistance, diëlectric, condenser, electro-magnet, galvanometer? (1.6)

403. How much current will an electro-motive force of one volt drive through a resistance of one ohm? (1.9)

430. The number of watts equals the product of voltage and what? (1.6)

5.2

361. What is the common name for the rotating part of a dynamo, consisting of the coil and its core? (1.6)

369. With what kind of a cell should the circuit be kept open when not in use? (1.9)

384. What is the common name of the device used to change electrical energy at high voltage to electrical energy at low voltage? (1.6)

5.4

380. What is the common name of the device which converts the energy of electrical currents into mechanical energy? (1.8)

387. Which will yield the more heat:
(a) a 50 ohm resistance connected across a 50 volt line, or
(b) a 100 ohm resistance connected across a 100 volt line? (4.0)

394. What kind of electrification appears on sealing-wax or hard rubber when rubbed with flannel or fur? (1.6)

5.6

349. How should two cells be connected in a circuit in order to reduce the effect of internal resistance? (2.9)

368. When there is a difference of potential between two points and the two points are connected by a good conductor, what occurs? (4.6)

370. What is the unit of electro-motive force? (2.2)

371. When a conductor is brought near a positively charged body, what kind of electricity is repelled to the farthest end? (1.2)

377. Will a solid sphere hold a larger charge of electricity than a hollow one of the same diameter? (1.4)

386. The resistance of a conductor is directly proportional to what? (2.5)

399. Three wires whose resistance are 10, 12, and 14 ohms respectively, are arranged in series; what is their joint resistance? (2.3)

416. The following incandescent lamps are all suitable for use in a 110 volt lighting system: 40 watt, 60 watt, 80 watt, 100 watt. Which one of the four has the least resistance? (2.7)

432. An electroscope positively charged will show divergence of the gold leaves. If it were negatively charged, would the gold leaves diverge? (1.2)

5.8

341. If the right hand grasps the wire so that the fingers encircle the wire in the same direction as do the magnetic lines, and the thumb extends parallel to the wire, which way is the current flowing? (2.7)

366. To get the heating effect of a current we multiply the number of ohms of resistance by the number of seconds of time by the number of calories equivalent to one joule; then multiply by what else? (multiply 0.24 Rt by what?) (4.4)

383. The resistance of a battery is 3 ohms, and it drives a current of .5 amperes through an external resistance of 1.5 ohms. What is the electro-motive force of the battery? (4.3)

396. What is it that attracts the needle of a compass and makes it take a north-and-south direction? (2.1)

398. What kind of positive and negative static electricity is formed on a conductor in the neighborhood of a charge? (5.0)

434. If a certain substance has great permeability can magnetism be easily induced into it? (1.4)

6.0

347. What are all the molecules of iron or steel, according to the common theory that accounts for magnetism? (3.1)

385. What is the common name of the unit of power which keeps a current of one ampere flowing under a drop of one volt? (2.2)

410. Magnetism is induced in a wire nail by the north pole of a magnet. The nail is in a position parallel to the magnetic lines of force with its head toward the magnet. Will the point of the nail be a north pole or a south pole? (3.5)

423. A storage cell has an E. M. F. of 2 volts and furnishes 3 amperes of current. At what rate in watts is it spending energy? (2.9)

6.2

345. An electroscope is charged with negative electrification. What kind of electrification will increase the divergence of the gold leaves when brought near, but not near enough to allow a spark to pass? (2.4)

346. From the following select one which is a good conductor of current electricity: glass, pure water, graphite, dry air, paper. (2.1)

351. If a 110-volt incandescent lamp takes a current of .5 ampere, what is the resistance of the lamp? (2.8)

392. There are four main parts in an induction coil: circuit breaker, primary coil, secondary coil, and what? (2.5)

402. What property of a volt-meter prevents it from short-circuiting the two lines when connected across? (2.8)

6.4

360. In what form is the energy stored in a storage battery? (3.1)

393. With what kind of a cell should the circuit be kept closed when not in use? (2.0)

411. Sometimes combing one's hair with a rubber comb will produce electrification in the hair. Is it positive or negative? (2.0)

417. A transformer has 10 turns of wire in the primary for each turn of wire in the secondary coil. The voltage in the primary is 110, what is the voltage in the secondary? (2.7)

6.6

422. The resistance of a conductor is inversely proportional to what? (2.7)

6.8

344. What property of an electric current is utilized in comparing currents by means of a galvanometer? (3.1)

412. What is the common name applied to the deviation from the true north-and-south line of a compass needle free to swing in a horizontal plane? (1.7)

424. At 15 cents per kilowatt hour, what will it cost to run for 10 hours a 220-volt motor drawing a current of 25 amperes? (4.4)

429. If the current through an incandescent lamp is .55 ampere and the potential difference between its terminals is 110 volts, what is its resistance? (2.9)

7.0

340. In an electric circuit two resistances of 3 ohms and 12 ohms, respectively, are arranged in parallel. The current through the 3 ohm resistance is 2 amperes, what is the current through the 12 ohm resistance? (4.0)

354. What happens to water while it is a part of an electric circuit? (2.2)

389. Two wires of the same material but of diameters in the ratio 1 to 2 are connected in series in the same electrical circuit. The fall of potential in the larger wire is 1 volt per foot of length. What is it in the smaller wire? (3.8)

397. The capacity of a condenser depends on the distance between the plates, the dielectric between the plates and what else? (3.7)

413. The capacity of a condenser depends on the dielectric between the plates, the distance between the plates, and what else? (2.3)

7.2

428. Three cells each have an E. M. F. of 2 volts and an internal resistance of .05 ohms and they are arranged in series to drive a current through an external resistance of 8.85 ohms. What is the current? (5.7)

7.4

339. A copper wire is ¼ inch in diameter, and has a resistance of 12 ohms; what is the resistance of another copper wire of the same length but having a diameter of ½ inch? (2.8)

7.6

336. What is the common name for the quantity of electricity that passes when one ampere flows for one second? (2.1)

350. If the current is one ampere what quantity of electricity will pass through a given point in 5 seconds? (3.9)

375. What is the common name for the number of degrees by which, at a given point on the earth, the magnetic needle varies from the true north-and-south line through that point? (2.7)

379. Three wires whose resistances are 10, 12, and 14 ohms, respectively, are arranged in parallel. What is their joint resistance? (6.7)

388. Two cells having an internal resistance of .08 ohms and an E. M. F. of 2 volts are arranged in parallel and drive a current of 1 ampere through an external resistance. What is that resistance? (7.7)

404. In a step-down transformer 1100 volts is the E. M. F. of the primary and 110 volts is the E. M. F. of the secondary coil. If the current in the secondary is 1 ampere what is it in the primary? (2.3)

406. Two pieces of wire have resistances of 75 and 125 ohms, respectively. What is their joint resistance when arranged in parallel? (6.7)

407. When N equal resistances, each of resistance R, are placed in parallel, what is their joint resistance in terms of N and R? (4.2)

7.8

359. What strength of current will deposit 10 grams of silver by electrolysis in one hour? (5.9)

378. What is the smallest known electrical charge? (1.1)

8.2

421. Three cells each having an internal resistance of .06 ohms and an E. M. F. of 2 volts are arranged in parallel to drive a current through an external resistance of 3.98 ohms. What is the current? (4.5)

431. How much silver is deposited by a current of 1 ampere flowing through a solution of silver-nitrate for 15 minutes? (5.5)

8.4

405. If the E. M. F. of a lead cell is 2.3 volts on open circuit, and the terminal voltage when delivering 10 amperes is only 2 volts, what is the internal resistance of the cell? (7.3)

420. Two wires of the same material are found to have resistances of 6 and 10 ohms, respectively. If the diameter of the first is 8 millimeters, what is the diameter of the second? (5.7)

9.0

337. If the resistance between two points is 25 ohms, what will be the resistance of an additional wire connecting these points, in order to make the joint resistance between the points only 20 ohms? (6.0)

### THE CORRECT ANSWERS

In Table IV, page 33, all the exercises are listed by number in numerical order and the correct answers given. Also, in the case of most of the exercises, the more typical wrong answers are given at the right hand side of the page. For example, all answers to exercise No. 1 that were considered correct are: ⅖ H. P., 0.4 H. P., 0.4, and ⅖; and the typical wrong answer was 4. For exercise No. 19 the only correct answer is "power," and several wrong answers are given.

### TABLE IV

Correct and Incorrect Answers

| *Exercise* | *Correct Answer* | *Incorrect Answer* |
|---|---|---|
| 1. | 2/5 H. P., 0.4 H. P., or 0.4, or 2/5 | 4 |
| 2. | 20 feet | 10 ft., or 20 |
| 3. | shortened | lengthened |
| 5. | 13.6 or 13.6 grams | |
| 6. | weight | gravity, velocity, gravitation, pounds |
| 7. | velocity, or speed | weight, force |
| 8. | 4/5, 80%, or .80 | |
| 9. | barometer | |
| 11. | 100 lbs. | 25 lbs., or 100 |

| | | |
|---|---|---|
| 12. | 500 dynes | 500 grams, or 500 |
| 13. | dyne, or 1 dyne | joule, velocity, pound, gram-centimeter |
| 14. | acceleration | gravity, speed |
| 18. | 2.6 feet, 2.6, or<br>2.6 feet apart | 1.8 feet |
| 19. | power | kilowatt, speed, velocity, horse-power, work, ft.-lbs. |
| 20. | 20, or 20 times | 40 times, 10 times |
| 21. | 5 cu. ft. | |
| 25. | 402 feet | 160.8, or 402 |
| 26. | 0, zero, naught | |
| 31. | erg, dyne-centimeter | joule, gram, watt, gram-centimeter, potential energy |
| 32. | 0, 0 cm. per sec. | 10 cm. per sec., 1 cm. per sec. |
| 33. | elastic limit | work, elasticity, bending, strain |
| 34. | diagonal | bisector, hypotenuse |
| 35. | power | |
| 36. | 50, 50:1, or 50/1 | 100% |
| 38. | 3120, 3120 lbs.,<br>3120 per sq. ft.<br>3120 lbs. per sq. ft. | 3120 ft.-lbs.<br>312 |
| 39. | cohesion | adhesion |
| 40. | 21.6, or 21 and 2/3<br>21.6 lbs. per sq. in. | 3120, 3120 ft.-lb. |
| 43. | 263.9 in., (262.9 to 264.9) in.,<br>21.99 ft., or 22 feet.,<br>(21.89 to 22.09) ft. | 84 in. |
| 44. | 10560 sec., 176 min.<br>2.93 hr., 2 hr. 56 min. | 2 hr. 54 min.,<br>3 hr. |
| 45. | 40, or 40 inches<br>(39.8 to 40.2) | 4 inches |
| 46. | 980 cm. per sec. per sec. | 1 cm. per sec. per sec.,<br>1 gram, 980 cm. |
| 47. | gravity, gravitation | |
| 48. | 250, or 250 ft-lb.<br>3000 inch-lb. | |
| 49. | V squared, or<br>velocity squared | distance, velocity,<br>$MV^2$, or $MV^2/2$ |
| 52. | d:s, or d/s | ds, s/d, or 1:2 |
| 54. | inertia, momentum | rate of speed |
| 55. | 2 seconds | 4 sec., 1 sec.,<br>or same |
| 56. | 120, 120:1 | 1/120, 1:120 |
| 57. | atmospheric pressure,<br>air pressure | pressure, density,<br>humidity |

| | | |
|---|---|---|
| 58. | 4/5, .8, or 80% | 1/5 |
| 62. | 48.332 ft. per sec., or<br>(48.092 to 48.572) ft. per sec. | |
| 63. | 94,248 ft-lb., or<br>(93,777 to 94,719) ft-lb. | 188,496 ft.-lb. |
| 65. | gram, or 1 gram | |
| 66. | acceleration due to gravity,<br>gravitation, or gravity | density, volume<br>surface area,<br>dyne, gram,<br>potential,<br>center of gravity |
| 67. | .1 ft. per sec. per sec.<br>6 ft. per sec. per min. | 6 ft. per sec., 6,<br>6 ft. per sec. per<br>sec., or 6 ft. |
| 71 | 4 times as much<br>4 cm. | 4 |
| 72. | K. E. equals 1000,<br>1000 ergs, 1000 | 200 grams, 200 cm.,<br>200, or 1000 gm. |
| 73. | 31,680,000<br>31,680,000 ft-lb. | 16 ft.-lb., or 16 |
| 75. | inertia | force, time,<br>centrifugal force |
| 76. | 1/4 as long, 1/4 | 1/2<br>square root of 1/2 |
| 81. | cohesion,<br>cohesive force | adhesion, pressure,<br>vacuum, gravity,<br>surface tension |
| 82. | 150, 150 cu. ft.<br>100 times as much | 16½ |
| 83. | 150 in., 12½ ft. | 165 in., 150<br>150 ft., or 16½ |
| 84. | 484 ft. | 11 ft., 484 |
| 85. | cohesion,<br>cohesive force,<br>surface tension | gravity,<br>centrifugal force |
| 89. | 30 cm. per sec. | 30 cm., 25 cm.,<br>30 dynes |
| 91. | force applied, force | |
| 92. | kinetic, kinetic energy | potential |
| 94. | 2 sec. | 2 min., 20 min.,<br>20 sec. |
| 95. | 64.32 ft. per sec. per sec. | 64.32 ft. per sec.,<br>64.32 lb., 64.32 |
| 96. | .5 sec., ½ sec. | 5 sec., 5 min.,<br>or .05 sec. |
| 100. | ¾, or .75 | 1 and 1/3, or .66 |

| | | |
|---|---|---|
| 101. | 1020 grams | 55, 102, 1020 |
| 102. | 375 lb. per sq. in.,<br>375 lb. | |
| 103. | 80 joules,<br>800,000,000 ergs,<br>816,326.53 gm-cm.,<br>(812244 to 820408) gm-cm. | 4,000 40,000<br>4,000 gm-cm., 4,000 gm-m.,<br>40,000 gm-cm., 8163265 |
| 104. | .92, or .92 per cu. cm. | 108, 1.08, 108 gm. |
| 108. | 124,750 ft-lb., or<br>the former is 500 times<br>the latter | the same<br>no difference |
| 109. | 2.5 ft. in length,<br>2.5 ft. | 2 ft. |
| 110. | work, or energy | |
| 111. | 98 meters per sec.,<br>9800 cm. per sec. | 9800 cm. |
| 112. | center of gravity | fulcrum, mass,<br>equilibrant, gravity |
| 113. | 5,000 ft-lb. | 5,000 |
| 118. | .1 H. P., or .1 | 55 H. P., 1 H. P.,<br>6 H. P., .0016 H.P. |
| 119. | same, or 20 dynes | 10 dynes |
| 120. | capillary, or<br>capillary action,<br>or absorption | porosity |
| 121. | (29.85 to 30.15) in. | 3 in., 27½ |
| 122. | 5 cu. ft.,<br>1/20 as much | 2000 cu. ft.,<br>45 cu. ft. |
| 126. | 1437.5 ft-lb.,<br>(1430 to 1445) ft- lb. | 1500 ft.-lb.<br>3000 ft-lb |
| 129. | distance, space,<br>displacement | time, speed,<br>velocity |
| 130. | 12 sec. | 72 sec., 4.7 sec. |
| 131. | potential,<br>potential energy | force, gravity,<br>kinetic, work |
| 135 | heavier, latter | lighter |
| 137. | 3, 3:1, 3/1, 3 to 1. | 1/3, 1/6, or 6 |
| 138. | 3/2, 1.5, 1½. | 2/3 |
| 139. | 13.6, 13.6 gm.<br>13.6 gm. per cu. cm. | |
| 140. | 20.4 in., 1.7 ft. | .772, or 20.4 |
| 144. | 112,500 ft-lb.<br>(111,937 to 113,062) ft.-lb. | 75,000 ft-lb |
| 145. | 1,980,000 lbs.<br>990 tons. | 198,000 lbs.,<br>19,800,000 lbs. |

| | | |
|---|---|---|
| 146. | 41,666.6 cu.ft.<br>(41,459 to 41, 875) cu. ft. | |
| 147. | 8 cm. per sec. | 16 cm. per sec |
| 148. | 220,000 gm-cm.,<br>215,600,000 ergs,<br>21.56 joules,<br>2.2 kgm-m. | 2.2, 22,000<br>220,000 |
| 152. | 6 in., .5 ft. | |
| 153. | distance, height,<br>displacement | time, mass, speed,<br>resistance, momentum |
| 154. | northeast | north, east, south,<br>southeast |
| 155. | resistance, load,<br>weight | gravity, energy,<br>pull, work-done |
| 156. | acceleration of gravity,<br>32.16 ft. per sec. per sec.<br>32.2 ft. per sec. per sec. | acceleration,<br>pull of gravity,<br>gravity |
| 157. | density | gram, grams, mass. |
| 161. | in fine dirt,<br>fine dirt | coarse dirt, coarse |
| 162. | 2592 times pi lbs.,<br>8143 lbs.,<br>(8102 to 8184) lbs. | 8143 |
| 163. | burst out, out,<br>toward street | toward the store,<br>cave in |
| 164. | 346.1 ft., or<br>(344 to 348) ft. | 150 ft. |
| 165. | 1,000,000 ergs,<br>1,000,000 dyne-cm.,<br>10,000 dyne-meters,<br>.1 joule, 1020.4 gm-cm. | 1,000,000 dynes,<br>1,000,000, or<br>1,000 gm. |
| 166. | 10 sec. | |
| 171. | 40 lbs. | 80 lbs., 40 |
| 173. | 1/9, or latter equals<br>1/9 of the former | 1/3, 3 times,<br>3 times as long |
| 174. | adhesion<br>adhesive force | cohesion |
| 175. | 820.31, 820.31cm.,<br>(816 to 824) cm. | 76 cm., 7.6<br>810 |
| 179. | 1 mm. tube, 1 mm.,<br>the former, smaller | both the same,<br>same, 2 mm. |
| 180. | 234 lbs., or<br>(233 to 235) lbs. | 78 lb., 2.66 lb.,<br>19.5 lb., 312 lb.,<br>.04 lb., 365. |
| 182. | 79,200,000 ft-lb. | 132,000 ft.-lb.<br>79,200,000 |

| | | |
|---|---|---|
| 183. | 112 rev. per min., or<br>(111.4 to 112.6) rev. per min.,<br>1.87 rev. per sec., or<br>(1.86 to 1.88) rev. per sec. | 672 rev. per min. |
| 184. | 50,000 ft-lb. | 50,000 |
| 188. | 2, or 2 gm. | 40 gm., 200 gm. |
| 191. | 8 ft. | 60 ft., 8. |
| 197. | 253.6 in., or<br>(352 to 355) in.,<br>29.46 ft., or<br>(29.31 to 29.61) ft. | 29.4 |
| 198. | 6700 ft., or<br>(6664 to 6734) ft. | 1300 ft. |
| 199. | 1039.2 lbs., or<br>(1034 to 1044.4) lbs. | 900 lbs., 800 lbs.,<br>1200 lbs. |
| 200. | 108 dynes,<br>.1102 grams of force. | 108 gm., 12 gm. |
| 201. | velocity, speed. | distance |
| 202. | energy | kinetic energy,<br>foot-pounds<br>power, horse-power<br>efficiency. |
| 206. | time, the period,<br>time of one vibration | |
| 207. | 748,800 lbs., or<br>(745,056 to 752,544) lbs. | 12,000 lbs. |
| 208. | adhesion | magnetism, cohesion,<br>magnitude,<br>molecular attraction |
| 209. | 1033.6, or 1033.6 gm.,<br>(1028.4 to 1038.8). | 15 gm., 76 cm. |
| 210. | toward the center,<br>toward | away, out |
| 215. | moment,<br>moment of force | lever, normal |
| 216. | length,<br>length of pendulum | distance |
| 217. | density | |
| 218. | 60 ft., 720 in.,<br>(59.7 to 60.3) ft.,<br>(716 to 724) in. | 26 ft., 806 ft.<br>858 ft. |
| 219. | 29.134, 29.134 in.,<br>(29 to 29.3). | 25.19 in.,<br>2960 in. |
| 220. | 1140 gm., 1.14 kgm. | 1140, 114 gm.,<br>1140 cu. cm. |
| 224. | cohesion | adhesion, magnetism |

| | | |
|---|---|---|
| 227. | 288 lbs. | 72 lbs., 280 |
| 231. | 68 degrees,<br>68 degrees F. | 40, 68 |
| 232. | 300, 300 degrees | 27 degrees, 270 |
| 233. | calorie, 1 calorie | specific heat |
| 234. | aluminum | brass |
| 235. | (b) | (a), (c) |
| 236. | 240.4 in., 20.033 ft.,<br>(239.2 to 241.6) in.,<br>(19.933 to 10.133) ft. | 240.38 ft., 11.6 ft.,<br>.00026, 20.033,<br>240.38 |
| 237. | increase,<br>increase the pressure | decrease |
| 238. | 25.168 gm.,<br>(25 to 25.3) gm. | 150 gm., 250 gm.<br>25.14 |
| 239. | radiation<br>radiant heat transmission | convection, induction,<br>convection currents,<br>conduction |
| 242. | 3, 3 times | 2 times, 4 times |
| 243. | will be lowered | thermometer will fall |
| 244. | iron | water |
| 245. | 25, 25 degrees C. | 7.22 degrees C. |
| 246. | to cool the engine | |
| 247 | temperature, heat-level,<br>thermal condition,<br>hotness of a substance,<br>degree of hotness,<br>heat intensity | heat and cold,<br>amount of heat,<br>heat pressure,<br>pressure of air |
| 248. | 9,000, 9,000 cal. | 90 cal., 9000 gm. |
| 253. | —40 degrees,<br>—40 degrees F. | —18 degrees F. |
| 254. | expansion,<br>volume expansion,<br>cubical expansion | linear expansion |
| 255. | 18.07 lbs per sq. in.,<br>(17.97 to 18.17)<br>lbs. per sq. in. | 60 lbs. per sq. in.,<br>45 lbs. |
| 256. | 31 degrees C. | 30 degrees C.<br>31 degrees |
| 257. | vacuum, air, wood,<br>water | |
| 258. | 300.255 ft., or<br>(300.2537 to 300.2563) ft. | 300.0255 ft.,<br>300.255 |
| 261. | convection | conduction, radiation |
| 262. | one, 1 calorie | 34,160 cal. |
| 263. | rough, the latter. | polished |

| | | |
|---|---|---|
| 264 | 14 liters, or | 273 liters, |
| | (13.93 to 14.07) liters | 14.61 liters |
| 265. | 84 degrees C. | 84 degrees |
| 267. | 9/17, (.52 to .53), 53% | |
| 270. | 180, 180 degrees | 212 degrees |
| 272. | specific heat | calorie, degree |
| 273. | —4 degrees | 68 degrees F. |
| | —4 degrees F. | |
| 274. | 2, 2 degrees | 50 degrees C. |
| 275. | copper, iron, stone | |
| 276. | 4.19x$10^{10}$, 4.19x$10^{10}$ ergs, | |
| | (4.179 to 4.221)x$10^{10}$ | |
| 279. | heat | moisture |
| 280. | 35 degrees C. | 20 degrees, 35 degrees |
| 281. | expansion, | rise in temperature |
| | volume expansion, | |
| | cubical expansion | |
| 282. | 273 degrees, | —273 degrees |
| | 273 degrees C. | |
| 283. | distillation, | boiling, evaporation, |
| | | filtration |
| 284. | 273 degrees, 273 | 0 degrees |
| 288. | copper | aluminum |
| 289. | radiation | |
| 290. | 17,000, 17,000 cal. | 720,000 |
| 291. | 1:2, .50, 50% | 50 |
| 292. | 1/273, .003663 | |
| 295. | 20 gm. | 20 lbs., 20, |
| | | 500 gm., 5000 |
| 297. | thermometer | |
| 299. | heat | |
| 300. | coefficient of cubical | calorie, expansion, |
| | expansion, coefficient | specific heat, |
| | of volume expansion, or | cubical expansion |
| | coefficient of expansion | |
| 301. | 4 degrees C. | 37 degrees F. |
| | | 0 degrees C., |
| | | 4 degrees |
| 302. | diminished, decreased, | increased |
| | the latter | |
| 303. | 22.2, 22 and 2/9, | 40 degrees C. |
| | 22.2 degrees C. | 27 and 7/9 degrees |
| 304. | 95 degrees C., | 194 degrees F. |
| | the first | |

| | | |
|---|---|---|
| 307. | convection | conduction |
| 308. | convection | radiation |
| 309. | mechanical equivalent of heat | ergs, grams, ft-lb., 14.9 joules, B. T. U. |
| 310. | 7200, 7200 cal. | 5400 cal. |
| 311. | no. | |
| 312. | salt water | fresh water |
| 313. | distance squared, square of distance from the source. | pressure, distance |
| 314. | 1/5, .2, .2 cal. | |
| 317. | conduction | radiation |
| 318. | 1000, 1000 cal. | 42,700,000, 1 cal. |
| 319. | no | yes |
| 320. | yes | no |
| 321. | good conductor of heat, better heat conductor, carries the heat away | |
| 322. | 180, 180 degrees, 180 F. degrees | 212 degrees F. |
| 323. | 1121.52 cu. cm., or (1115.9 to 1127.1) cu. cm. | 3333.33, 300 cm. |
| 325. | yes | |
| 326. | the latter | the former |
| 327. | 1.25 gm., 1¼ gm. | 53375 grams |
| 328. | 1/273, .003663, or increase in going from 0 to 1 degree C., or increase in volume divided by the product of original volume times the temperature change | |
| 329. | rough surface. | smooth surface |
| 330. | reflects heat, reflects radiant energy, retains heat longer, less surface for radiation, polished surface is a poor radiator. | absorbs heat faster, bottom absorbs heat |
| 331. | evaporation uses heat, evaporation causes cooling, evaporation takes heat from surroundings | vaporization, water absorbs heat, more vapor in air |

| | | |
|---|---|---|
| 332. | salt causes ice to melt and absorb heat from the cream, salt lowers melting point, salt lowers freezing point, salt melts ice and melting ice absorbs heat, makes the ice melt faster | to make air cold, salt absorbs heat, dissolving salt takes up heat |
| 333. | iron | glass |
| 334. | becomes negatively charged, becomes negative, negatively charged | |
| 336. | coulomb, 1 coulomb | volt, watt |
| 337. | 100 ohms | 15 ohms |
| 338. | 1 ampere | |
| 339. | 3 ohms | 24 ohms, 6 ohms |
| 340. | .5 amp., ½ amp. | 6 amp., 8 amp., 4 amp. |
| 341. | in the direction the thumb points | north, east |
| 344. | magnetic, magnetic property | amperes |
| 345. | negative | positive |
| 346. | graphite | glass, pure water, paper, dry air |
| 347. | magnets, small magnets | conductors of electricity |
| 348. | E/R, e. m. f. / resistance | I equals ER |
| 349. | parallel, multiple | series |
| 350. | 5 coulombs | 5 volts, 5 amperes |
| 351 | 220 ohms. | 22 ohms, 55 ohms, 220 volts |
| 354. | electrolysis, decomposed into H and O, or decomposition, | becomes electrode, becomes changed, becomes conductor |
| 357. | on outer surface | all through, inner |
| 358. | amber, dry air, paper, pure water. | graphite |
| 359. | 2.484 amp., 2.4 amp., 2.5 amp. (2.4 to 2.5) amp. | 2 amp., 2.2 amp., 4 amp., 6 amp., 10 amp. |
| 360. | chemical, potential energy of chemical separation | static, potential, energy, electrical, electricity |

| | | |
|---|---|---|
| 361. | armature | solenoid, rotator, motor |
| 364. | 100 ohms. | 100 |
| 365. | volt, 1 volt. | volts |
| 366. | current squared, amperes squared, $I^2$, or $C^2$ | |
| 368. | flow of electricity from high to low potential, current flows, current | |
| 369. | Leclanche cell, storage cell, dry cell | gravity, voltaic |
| 370. | volt | volts, erg, watt |
| 371. | positive | negative |
| 372. | generator, dynamo, electric generator | transformer, motor |
| 375. | declination | magnetic pole, deviation, north pole, dip, deflection |
| 376. | positive | negative |
| 377. | no. | yes |
| 378. | electron | ion, watt, ampere |
| 379. | 3.925 ohms, or (3.9 to 3.95) ohms | 12 ohms, 36 ohms |
| 380. | motor electric motor | transformer, dynamo, electromagnet, commutator |
| 383. | 2.25 volts | 9 volts, 2.25, 2.25 e. m. f. |
| 384. | transformer | rheostat |
| 385. | watt, 1 watt | joule, ohm |
| 386. | length (of conductor). | material, size, area of cross-section |
| 387. | (b) | (a) |
| 388. | 1.96 ohms, (1.95 to 1.97) ohms | 3.84 ohms, 1.84 ohms, 1.92 ohms, 25 resistance |
| 389. | 4 volts | ¼ volt, 2 volts, .5 |
| 392. | iron core, condenser | electro-magnet, electric field, magnetic field |
| 393. | daniell cell, gravity cell, crow-foot cell | wet cell, battery, dry cell, Leclanche, galvanic, voltaic |
| 394. | negative | positive |

| | | |
|---|---|---|
| 395. | condenser | resistance,<br>galvanometer |
| 396. | earth's magnetic field,<br>earth's magnetism,<br>north magnetic pole,<br>earth's magnetic pole | magnetism, magnetism<br>of the poles,<br>magnetic field of the<br>north and south poles |
| 397. | area of the plates,<br>size and number<br>of plates | kind of plates,<br>insulator, resistance,<br>material of plates,<br>internal resistance,<br>electric cell,<br>strength of charge |
| 398. | induced,<br>opposite kind | permanent, static,<br>alternating,<br>same kind |
| 399. | 36 ohms | |
| 402. | resistance,<br>high resistance | insulator, shunt,<br>low resistance |
| 403. | 1 ampere | 1 volt |
| 404. | .1 ampere | 10 amperes |
| 405. | .03 ohm | 3 volts, .2 ohm,<br>1.15 ohms |
| 406. | 46.15 ohms, or<br>(45.92 to 46.38) ohms | 97.5 ohms, 195 ohms |
| 407. | R/N, R divided by N. | 1/NR, N/R, NR/N,<br>N times R, N plus R,<br>R/2, N equals RN,<br>N equals R,<br>N equals N plus R. |
| 410. | north, north-pole | south-pole |
| 411. | positive | negative |
| 412. | declination | magnetic dip, deflection,<br>geographic poles,<br>angle of deviation,<br>angle of inclination |
| 413. | area of the plates,<br>size and number<br>of the plates | amount of current,<br>e, m f. |
| 414. | polarized | |
| 415. | 110, 110 volts | 11000 |
| 416. | 100 watt,<br>100 watt lamp | all the same |
| 417. | 11 volts, 11. | 1100 |
| 419. | less resistance,<br>better conductor | |
| 420. | 6.196 mm., 6.mm. plus | 4.8 mm., 13.3 mm. |

| | | |
|---|---|---|
| 421. | .5 amp., ½ amp. | .5 volts<br>.5 amperes plus |
| 422. | area of cross-section,<br>square of diameter,<br>square of radius | diameter,<br>distance squared,<br>length |
| 423. | 6, 6 watts. | |
| 424. | $8.20, $8.25, $8.30 | $0.825, $8.35,<br>$3.75, 8.25 |
| 425. | glass, hard rubber,<br>paper, pure water | |
| 428. | 2/3 amp., .666 amp. | 15 amperes |
| 429. | 200 ohms | 20 ohms, 2 ohms |
| 430. | current, amperes,<br>amperage | resistance |
| 431. | 1.0062 gm., or<br>(1.0012 to 1.0112) gm. | .1062 gm., .0167 gm.,<br>1.0062 |
| 432. | yes | no |
| 433. | yes | no |
| 434. | yes | no |
| 435. | ohm | ampere |

## DISCUSSION OF THE SCALES AND TESTS AVAILABLE

### FORMATION OF TESTS FROM THE SCALES

A number of different kinds of tests may be formed from these scales. Tests for any one, or for any combination of one or more, of the three phases of physics are possible. These tests may be rate-tests or power-tests.

In forming these tests several things should be observed quite carefully. Rate-tests should not include the most difficult exercises and the assigned values should be modified somewhat according to the "average time" shown for each exercise. For example, of the exercises on Mechanics (Table III-A), having a value 5.4, exercise No. 166 has an "average time" of twice as much as the "average time" of exercise No. 104. Evidently, in a rate-test including both exercises, twice as much credit should be given for No. 166 as for exercise No. 104. To avoid the necessity of modifying the values, it would perhaps be better to select exercises having the same "average time," or nearly so.

In forming a power-test, it is desirable to have at least 10 exercises, ranging, in uniform steps, from very easy to very hard. Try to avoid a test in which some individuals will get none and some others will get all the exercises correctly; for a score of 0 or a score of 100% does not really measure the ability of the individual.

The "average time" is quite valuable in suggesting the amount of time to allow for any given set of exercises. Since these units are *half minutes* (30 seconds), it may be well to allow just as many *minutes* as the total number of *units* of "average time" of the exercises of any particular test. For example, if the summation of the units of "average time" for a given set of exercises making up a diagnostic test is 40 units, then it may be well to allow 40 minutes for that test. This allows twice the "average time" required by those solving the exercises correctly. The following are two sample tests for Mechanics, for each of which 45 minutes should be allowed:

| | *Test (a)* | | | *Test (b)* | |
|---|---|---|---|---|---|
| Value | Exercise | Av. Time | Value | Exercise | Av. Time |
| 3.4 | 9 | 1.7 | 3.8 | 47 | 1.5 |
| 4.2 | 113 | 2.8 | 4.4 | 3 | 1.5 |
| 4.8 | 210 | 1.7 | 5.0 | 184 | 3.8 |
| 5.4 | 104 | 2.9 | 5.4 | 11 | 2.2 |
| 5.8 | 8 | 4.8 | 5.8 | 100 | 2.5 |
| 6.2 | 48 | 4.3 | 6.2 | 13 | 2.1 |
| 6.8 | 21 | 5.3 | 6.4 | 122 | 5.0 |
| 7.4 | 43 | 6.9 | 7.0 | 182 | 4.5 |
| 8.0 | 109 | 2.3 | 7.8 | 207 | 5.3 |
| 8.4 | 36 | 3.8 | 8.2 | 108 | 3.3 |
| 9.2 | 103 | 1.0 | 8.6 | 67 | 5.0 |
| 9.8 | 173 | 4.0 | 9.8 | 173 | 4.0 |

Similarly other tests may be formed for Mechanics, Heat, or Electricity and Magnetism, or for any combination of the three. If it be desirable to test only the knowledge of fundamental principles, such an aim should govern the selection of the exercises for the test. Great care should be exercised to avoid a selection of exercises such that the information given in any exercise is an aid to the correct solution of any of the exercises following it.

### LIMITATIONS OF THE TESTS

It is well to remember that any test measures only what it measures. A test of 10 or 12 exercises formed from these scales really measures ability to solve those 10 or 12 exercises. The ability of a given individual or group of individuals to solve the 10 or 12 exercises is doubtless a very good index of ability to solve that sort of exercises; and the score made on a few representative exercises is probably very nearly the same as it would be if a large number of such exercises were attempted. Physics ability, as measured by tests from these scales, includes ability to read and a certain amount of arithmetical ability. If a test of a given group shows the group to be below what they should be in ability to solve the problematic exercises, then it would be well to test the group on comprehension ability or power to solve mathematical problems, or both, by using available tests and scales designed for that purpose. Such diagnostic testing would greatly aid the teacher or supervisor in remedying the situation.

## DIRECTIONS FOR GIVING THE TESTS

In order that scores made by any given class may be comparable with scores made at a different time, or with scores made by other groups, it is necessary that the tests be given under the same conditions and that they be scored exactly as they were in deriving the values of the exercises. Consequently the directions here given should be followed strictly.

Before giving the tests to the pupils, be sure that each has a sharp pencil and extra paper for figuring. Also see that each one is seated where he will not be tempted to copy the work of another. Explain to the pupils that they will be given just so many minutes (40 or 50, as the test requires) to solve the list of questions. Their lists of questions will be put upon their desks face down, and they are not to turn the papers over or look at the questions until you give them the signal to "begin." Just as in any race, they must all start at the same time. But they must remember that *a correct answer is more important than speed and a wrong answer.*

Three signals will be given: "get ready," and each will get hold of his paper so he can turn it over quickly; "pencils up," and each will hold his pencil up in the air; "begin," and each will turn his paper over and begin. Direct them to start with the first question and answer them in order, but if the student cannot solve a certain question, he is to go ahead to the next. As soon as any one has finished all the questions, he will turn his paper over and sit quietly until all have finished.

After explaining the above method, read this sample problem: "A man carried a mass of 100 pounds to the top of a 10 foot ladder. How much work did he do?" Make the class understand that it is important to write *all* the answer, "1000 foot-pounds," for either part; "foot-pounds," or "1000," alone will count nothing. Ask if anyone has a question about what he is to do. Let some student volunteer to explain to the class what they are to do; then correct any mistakes or omissions he has made. Ask someone, "Which is more important, speed or correct answers?" Tell them not to ask any questions after the signal has been given to "begin."

Now pass out the questions, placing them face down upon the desks. Tell the pupils to fill in their names, ages, etc., in the spaces provided for that purpose. Then start them with the three signals: "get ready;" "pencils up;" "begin." When the time is up, collect all the papers.

## DIRECTIONS FOR SCORING THE TESTS

In order to eliminate the subjective element in scoring, it is necessary to observe certain definite rules and to follow them consistently. These rules must be simple and clearly stated, in order that every one using them may give the same score for any given solution of an exercise. For this reason the correct answers and a few of the most common incorrect answers for each of the exercises of the three scales have been listed in numerical order in Table IV. No credit is given for answers other than those listed in the table. This insures giving the correct score, whoever does the scoring.

To score a paper, mark each exercise which is correctly solved, find the sum of the values of those exercises, multiply this by 100, and divide the result by the sum of the values of all the exercises in the test. This gives the score in per cent. For example, consider test (a) on page 46. The sum of the values of all the exercises included in the test is 79.4. If an individual solve correctly the first, second, fourth, fifth, sixth, seventh, and ninth exercises, the sum of the values of the exercises correctly solved is 39.8. Multiplying this value by 100 and dividing by

79.4 gives 50.1 per cent for the score. Again, in test (b), on the same page, the sum of the values of all the exercises included in the test is 78.4 and for a person correctly solving the first 10 of the exercises (the sum of whose values is 60.0), the score is 60 times 100 divided by 78.4, which is 76.5 per cent.

### TENTATIVE STANDARDS

Tentative standards have been worked out for Iowa high school children. These are shown in Table V. These standards represent the scores made in the year 1920 and are the results of testing pupils on the work from 8 to 10 weeks after that particular phase of physics work had been finished and without doing any review work in preparation for the tests. Table V shows the number of cases involved in determining any given median as well as the quartile range for that group. These standards also show the median scores for boys, for girls, and for both boys and girls, for the different ages. A few children of age 14 are included in the group of age 15 years, and a very few of ages 22, 23, or 24 years are included in computing the median and quartile for the entire group of 3493 children.

TABLE V

TENTATIVE STANDARDS

| | | *Median Score* | | | *Quartile Range* | | |
|---|---|---|---|---|---|---|---|
| Age | Cases | Boys | Girls | Both | Boys | Girls | Both |
| 15 | 35 | | | 38.5 | | | 17.7 |
| 16 | 133 | 44.6 | | | 12.0 | | |
| 16 | 161 | | 36.6 | | | 13.2 | |
| 16 | 294 | | | 40.6 | | | 12.7 |
| 17 | 400 | 43.6 | | | 14.7 | | |
| 17 | 566 | | 33.4 | | | 13.3 | |
| 17 | 966 | | | 37.7 | | | 14.1 |
| 18 | 534 | 41.2 | | | 15.4 | | |
| 18 | 776 | | 33.7 | | | 14.2 | |
| 18 | 1310 | | | 36.5 | | | 14.6 |
| 19 | 296 | 40.0 | | | 13.8 | | |
| 19 | 303 | | 32.2 | | | 12.9 | |
| 19 | 599 | | | 35.6 | | | 14.1 |
| 20 | 108 | 35.6 | | | 14.5 | | |
| 20 | 66 | | 28.0 | | | 13.3 | |
| 20 | 174 | | | 32.5 | | | 14.2 |
| 21 | 52 | | | 42.5 | | | 14.7 |
| All | 3493 | | | 37.0 | | | 14.3 |

### VALUE AND USE OF THE SCALES

The three scales and the tests available therefrom, when properly selected, administered, and scored, should prove to be of considerable value:

(1) To the experimenter, as a means of comparing results of two or more methods of teaching the same subject matter;

(2) To the college or university, as a part of entrance examinations;

(3) To those making school surveys;

(4) To supervisors, in comparing progress and attainment of different classes or schools, results of different methods of teaching or of different classifications of pupils, for determining the amount of time to devote to different phases of the subject, and in determining what the course of study shall include;

(5) To teachers, in checking the results of teaching, as a guide in making the instruction more practical and valuable for all in a given group, and in determining the specific needs of individuals.

# BIBLIOGRAPHY


1. Ashbaugh, E. J., *Iowa Spelling Scales,* University of Iowa Extension Bulletins, Nos. 53, 54, 55 (1919).
2. Ayres, L. P., *Measurement of Ability in Spelling,* Russell Sage Foundation, Bulletin of the Division of Education (1915).
3. Buckingham, B. R., *Spelling Ability, its Measurement and Distribution,* Teachers College, Columbia University Contributions to Education, No. 59 (1913).
4. Chapman, J. C., 'The Measurement of Physics Information', *School Review,* XXVII (Dec. 1919), pp. 748–756.
5. Greene, H. A., *Status of the Sciences in North Central High Schools,* University of Iowa, Thesis (1917).
6. Greene, H. A., *Tests for Measurement of Linguistic Organization in Sentences,* University of Iowa, Dissertation (1919).
7. Hotz, H. G., *First Year Algebra Scales,* Teachers College, Columbia University Contributions to Education, No. 90 (1918).
8. Kelly, F. J., *The Kansas Silent Reading Test,* Bureau of Educational Measurements and Standards, Bulletin No. 3, Kansas State Normal School, Emporia, Kansas.
9. Monroe, W. S., *Measuring the Results of Teaching,* pp. 6–9.
10. Monroe, W. S., 'Monroe's Standardized Reading Tests,' *Journal of Educational Psychology,* IX (1918), pp. 303–312.
11. Starch, D., *Educational Measurements,* pp. 188 ff.
12. Thorndike, E. L., 'The Nature, Purposes, and General Methods of Measurements of Educational Products', *17th Year Book of the National Society for the Study of Education,* Part II, ch. 2, pp. 16–24.
13. Thorndike, E. L., 'An Experiment in Grading Problems in Algebra', *Mathematics Teacher,* VI (1914), pp. 123 ff.
14. Trabue, M. R., *Completion-Test Language Scales,* Teachers College, Columbia University Contributions to Education, No. 77 (1916).
15. Woody, C., *Measurements of Some Achievements in Arithmetic,* Teachers College, Columbia University Contributions to Education, No. 80 (1916).

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